Influence of habitat characteristics on the distribution of the water-rat (*Hydromys chrysogaster*) in the greater Perth region, Western Australia

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Abstract

This study investigated the distribution of the water-rat (*Hydromys chrysogaster*) in the greater Perth region, and proposes the potential of the species as a bioindicator of habitat quality. The degradation and loss of wetlands on the Swan Coastal Plain are associated with changes to habitat quality, including vegetation cover, stream cover, habitat diversity and bank stability. The occurrence of *H. chrysogaster* was analysed with respect to these factors at various water bodies around the greater Perth area. Sites positive for the presence of *H. chrysogaster* correlated with high value habitat quality characteristics, including high bank stability, habitat diversity, stream cover and foreshore vegetation. The presence of *H. chrysogaster* was not correlated to the occurrence and abundance of other local mammal species, except for a positive relationship with the introduced black rat (*Rattus rattus*) in relation to abundance. Based on the habitat requirements of *H. chrysogaster*, the species has some potential as a bioindicator of wetland condition on the Swan Coastal Plain, Western Australia, although the viability of such a method is uncertain.

Key words: wetland, habitat quality, bioindicator, rakali, Swan Coastal Plain

Introduction

Effective conservation of biodiversity in urbanised wetland areas requires an in-depth understanding of how aquatic species respond to changing habitat quality, water seasonality, and pollutant concentrations. Mammals have been used on numerous occasions as bioindicators of habitat quality, and this is especially true of small mammals such as rodents (Wren 1986). The water-rat (*Hydromys chrysogaster* Geoffroy 1804) is a native, semi-aquatic mammal that is common in some urbanised areas and especially in irrigation channels in the Eastern states of Australia (McNally 1960). Valentine *et al.* (2009) suggested that the success of populations of *H. chrysogaster* is critically linked with the persistence of important wetland ecosystems, and as a result *H. chrysogaster* may be used as an indicator species for Western Australian wetlands. Seventy percent of wetlands on the Swan Coastal Plain have disappeared since European settlement due to infilling, land clearing and over-drainage (Balla & Davis 1993; Davis *et al.* 1993). Of those remaining, many have become nutrient-enriched, saline, urbanised, subject to excessive groundwater extraction or contaminated by heavy metals and pesticides (Hill *et al.* 1996; Environment Australia 2001). Atkinson *et al.* (2008) hypothesised that vast degradation and salinisation of south-western water systems has lead to a substantial decline in western populations of *H. chrysogaster*. However, ecological studies on the health and abundance of Western Australian populations of the water-rat are few, especially in consideration of the current state of the wetlands on the Swan Coastal Plain.

Suitability of habitat is thought to be one of the factors influencing the distribution of mammals (Geier & Best 1980). Permanent water bodies on the Swan Coastal Plain have undergone detrimental habitat changes due to such processes as urbanisation, clearing, drainage, and livestock grazing (Davis *et al.* 1993). Habitat requirements for *H. chrysogaster* include areas suitable for dens or burrows (steep banks and/or logs) and some degree of vegetation cover (Scott & Grant 1997; Weir 2004). Previous trapping efforts for the species have been more successful where vegetated islands or reed beds were present close to the main bank (Valentine *et al.* 2009). However, no previous study has formally investigated the habitat requirements of *H. chrysogaster* and if these characteristics are related to habitat quality.

Habitat loss and fragmentation are significant factors contributing to species loss in south-western Australia, including frogs, waterbirds and mammals (GSS 2009). Pamment (1986) recorded 50 % of water-rat captures at man-made ponds, and Gardner and Serena (1995) recorded one-third of captures along similar, urbanised areas. Therefore, being common in urban, man-modified systems (Gardner & Serena 1995), *H. chrysogaster* is likely to be impacted by changes to water and habitat quality in urbanised catchments. Semi-aquatic mammals are in a "precarious" ecological niche because of the changing condition of water systems on the Swan Coastal Plain, in particular declining rainfall and groundwater levels that may also lead to decreased connectivity between wetland systems (Valentine *et al.* 2009). Declines in the number and size of populations of both water-rats and bush rats (*Rattus fuscipes*) on the Gnangara Mound, an important groundwater system, are possibly due to changes in permanent wetlands around Perth as a result of declining rainfall (GSS 2009). However, there are inconsistencies in the literature over the permanency of water required for *H. chrysogaster*, ranging from the species being able to survive on dry land and migrate long distances in agricultural areas (McNally 1960; Vernes 1998) to the requirement of permanent water (Scott & Grant 1997; Valentine *et al.* 2009). While these differences may be attributable to seasonal changes in behaviour, we do not have sufficient data to be sure. Hence the effects of habitat disturbance on this species are not well understood.

Effective conservation of urbanised wetlands requires an in-depth understanding of how well species adapt to changing habitat quality (bank stability, vegetation cover, habitat diversity, stream cover) and habitat structure (area, permanency of wetland), including the presence of other species. This study investigated the relative importance of these environmental and biological factors on the distribution of water-rats in the greater Perth region, Western Australia. This is particularly important in light of the degradation of many wetlands and lakes on the Swan Coastal Plain, and due to the species' position as a top order predator in these systems it may be used as a bio-indicator of the system quality. We investigated whether habitat structure and habitat quality contribute to the probability of *H. chrysogaster* presence.

Materials and Methods

Study Sites

Thirty-nine wetlands were investigated in the greater Perth metropolitan area, Western Australia, over a consecutive 13-week period (n = 3421 trap nights) from July to September 2009. The wetland study sites were both north and south of the Canning River running through the city centre, and were bordered by Yanchep National Park north of Perth, Rockingham to the south, and Mundaring in the Perth hills to the east of the main city (Fig. 1). Sites chosen were considered representative of the current state of lakes and wetlands in the greater Perth metropolitan area based on the wetland type, size and proximity to urbanised areas.

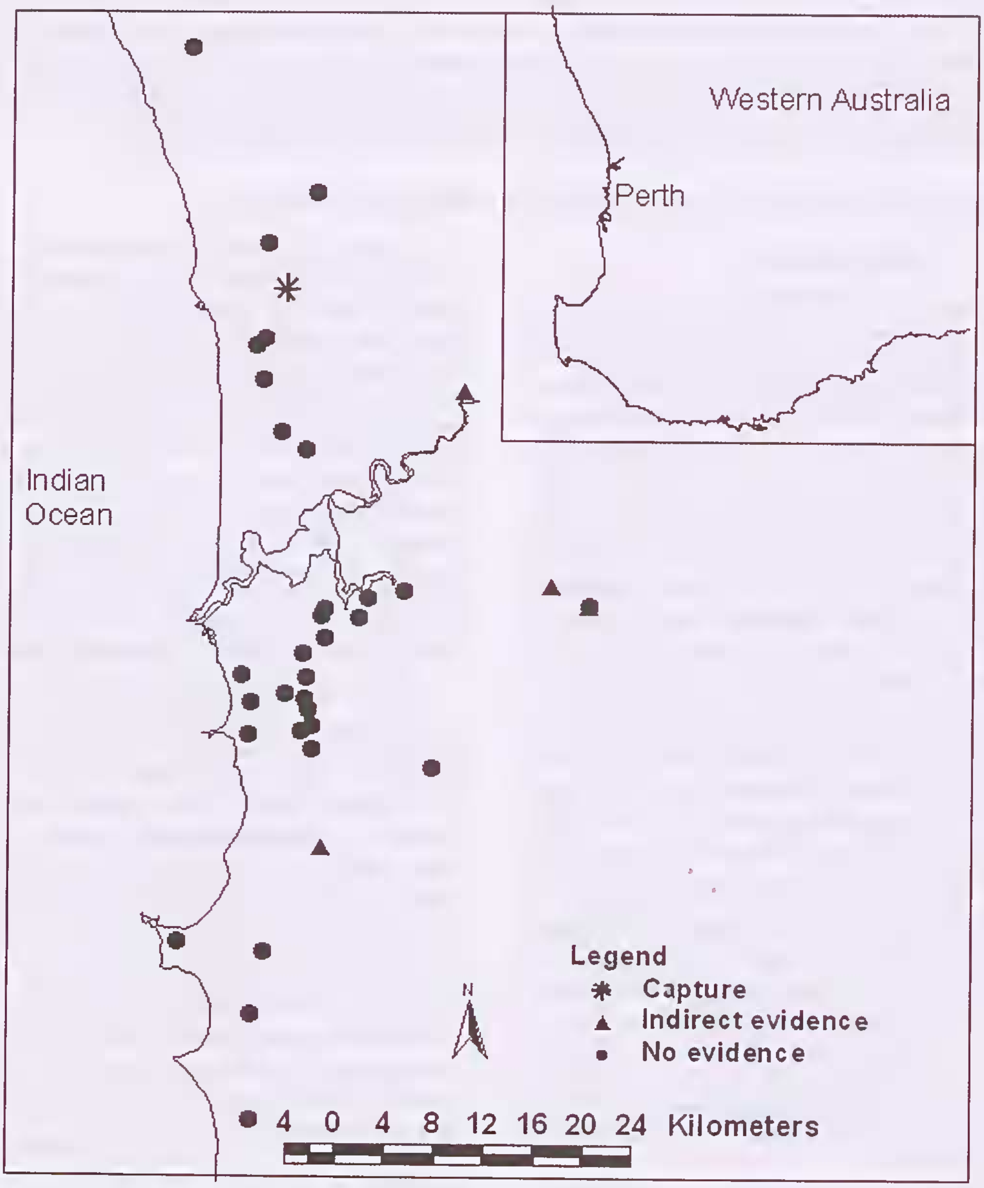

Figure 1. Map of sampling sites in the greater Perth region showing records of *Hydromys chrysogaster* as of October 2009.

Habitat Type

At each site, habitat quality characteristics were assessed by visual observation using the methods of Shepherd and Siemon from the Water and Rivers Commission (1999), with consideration of the EPA Bulletin *A Guide to Wetland Management in the Perth and Near Perth Swan Coastal Plain Area* (1993). Using these methods, four main habitat quality variables (vegetation cover, habitat diversity, stream cover, bank stability) were assessed, where each variable was given a condition index ranging from 0 (very poor) to 8 (excellent) based on a set of given parameters.

Water level data (Australian Height Datum; AHD m) were based on the records of the Department of Water (2005–2009). The average minimum water depth of each study site from the previous five years (2005–2009) was used to indicate the permanency of the water source, where water levels below 0.5 m were considered to be seasonally low. The area of open water of each study site (km^2), smallest distance between sites, and distance to the nearest water body from a site with *H. chrysogaster* was estimated using Google Earth Pro (Version 5.0).

Animal trapping

Wire cage traps were set at each site (n = 20–50/site) and baited with whole previously frozen pilchards. Traps were set at 20 m spacing across a continuum of habitat types, and set for 3–4 nights per site (3421 trapnights) from July (winter) to late September (spring). All traps were set facing the water and within 2 m of the water's edge.

Visual surveys were conducted along the trapped area of each study site for evidence of *H. chrysogaster* presence. These surveys were conducted daily and included observations of footprints, scats and the presence of feeding middens. Photographic evidence was taken of any visual signs of water-rat presence so that identification could later be double-checked against a field guide (Triggs 2004) or by other experts. Evidence of *H. chrysogaster* presence was supplemented by historical records of sightings and specimens provided by the Western Australian Museum dating from 1975, as well as from the management plans relevant to each wetland or lake. All non-target species trapped were noted, both native and introduced, as well as evidence of water-rat presence including scats, footprints and previous sightings.

Results

Evidence of *H. chrysogaster* was found at 7 of the 39 sites surveyed (18 %). This included direct captures at two sites (Lake Goollelal and Lake Joondalup [North]), captures by the Department of Environment and Conservation (Valentine *et al.* 2009) in the previous year at one site (Loch McNess), and evidence of presence at four sites (Canning River, Spectacles wetlands, Bennett Brook, Bickley Brook).

The size of each wetland sampled ranged from 0.02 km^2 to 4.26 km^2 (Table 1), where the average wetland size for positive sites was 2.0 ± 0.44 km^2. Binary logistic regression found a positive correlation between the presence of *H. chrysogaster* and the size of the wetland in which they were found (R^2 = 0.153, p = 0.018), indicating that the species may be more numerous where water sources are larger in area (Fig. 2).

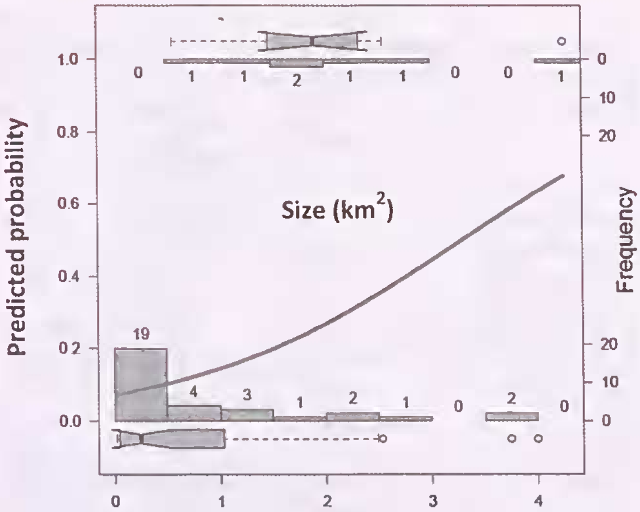

Figure 2. Nominal logistic regressions of size of wetland with *H. chrysogaster* occurrence (R^2 = 0.152, p = 0.018). Occurrence of *H. chrysogaster* is the designated y-variable where presence = 1 (n = 7) and absence = 0 (n = 32). Number of sites within each size category are labelled above each bar. ** denotes statistical significance $\alpha = 0.05$

Positive sites (sites with *H. chrysogaster* presence) were highly varied in distribution around the greater Perth area, ranging in proximity from 5–75 km apart ($\bar{x}$ = 31.95 ± 3.71 km). The average distance between a positive site and the nearest water body was 2.77 ± 0.93 km.

The occurrence of *H. chrysogaster* at the study sites was analysed in relation to the permanency of the water source, measured by the minimum water level (AHD m) since 2005. The logistic regression between these two variables was not significant (R^2 = 0.077, p = 0.598). A minimum water depth of 0.94 m was the lowest water level recorded since 2005 for any site supporting a population of *H. chrysogaster*.

The habitat quality scores for each parameter were significantly different between sites with and without *H. chrysogaster* (ANOVA, p = 0.006; Table 1). The seven positive sites formed a relatively tight group within this principal component space and therefore embrace similar environmental conditions in terms of habitat quality (Fig. 3). Increases in Component 1 reflected increasing vegetation cover (%), habitat diversity and stream cover, whereas increases in Component 2 reflected greater bank angle and stability. All core sites scored highly for Component 1, and half scored highly for Component 2. This observation was confirmed using 2-sample t-tests, where for both Component 1 (t-test, p = 3.22 x 10^{-7}) and Component 2 (t-test, p = 0.038), the sites positive for *H. chrysogaster* differed in their principal component values from those sites without *H. chrysogaster*. The sites with evidence of *H. chrysogaster* presence had higher vegetation coverage (79%) than those sites without *H. chrysogaster* (54 %) (t-test, p < 0.001). Sites with *H. chrysogaster* had steeper bank angles (60.0°) than those without any evidence of *H. chrysogaster* presence (19.7°) (t-test, p <0.001).

Table 1

Summary data of habitat variables for wetland sites positive and negative for the presence of Hydromys chrysogaster.

Positive	Size (km2)	Min water depth (AHD m)	Veg cover (%)	Bank angle	Bank stability	Stream cover	Habitat diversity
Bennett Brook	1.90	6.78	65	90	8	6	6
Bickley Brook	0.56	9.90	90	70	8	8	6
Canning River	1.64	0.94	75	80	8	8	6
Lake Goolellal	2.10	26.50	80	50	6	8	8
Lake Joondalup (North)	4.26	16.0	85	30	8	8	8
Loch McNess	2.55	6.60	75	70	8	6	6
The Spectacles	1.30	8.60	85	30	6	8	8
Average ± se	*2.0 ± 0.44*	*10.8 ± 3.13*	*79.3 ± 3.16*	*60.0 ± 8.99*	*7.4 ± 0.37*	*7.4 ± 0.37*	*6.9 ± 0.40*
Negative	**Size (km2)**	**Min water depth (AHD m)**	**Veg cover (%)**	**Bank angle**	**Bank stability**	**Stream cover**	**Habitat diversity**
Anstey Swamp	2.49	1.85	60	0	4	8	2
Bibra Lake	1.24	13.54	50	20	4	6	8
Blue Gum Lake	0.02	5.00	35	10	2	4	2
Booragoon Lake	0.04	10.00	55	20	4	6	2
Bull Creek	0.02	1.00	65	70	2	8	4
Carine Swamp	0.18	3.00	65	10	6	6	6
Forrestdale Lake	1.06	21.60	45	10	2	6	4
Herdsman Lake	2.40	6.32	35	0	4	8	8
Kogolup Lake (North)	0.35	3.00	60	30	6	6	6
Kogolup Lake (South)	0.12	3.00	65	30	6	6	6
Lake Coogee	0.52	0.17	45	40	6	4	6
Lake Cooloongup	3.75	1.42	60	40	6	6	8
Lake Gwelup	0.14	5.00	50	10	6	4	4
Lake Jandabup	2.53	44.10	80	0	6	8	6
Lake Joondalup (South)	0.14	3.00	70	20	2	8	6
Lake Marginup	1.01	41.17	70	10	4	8	4
Lake Monger	0.65	0.90	40	20	4	4	4
Lake Nowergup	0.29	16.09	55	10	4	6	6
Lake Richmond	0.27	0.14	45	40	4	6	6
Lake Walyungup	4.00	0.70	10	10	4	0	2
Little Rush Lake	0.04	2.50	70	10	6	6	6
Little Carine Swamp	0.03	5.00	50	70	6	6	6
Manning Lake	0.05	0.11	65	0	2	4	6
Market Garden Swamp	0.03	0.11	45	20	6	4	4
Mundaring Weir	0.67	20.30	40	20	6	0	4
North Lake	0.22	12.38	60	10	4	6	6
Piney Lakes	0.15	2.20	60	0	2	8	6
Quenda Wetlands	0.02	2.10	75	30	6	6	4
South Lake	0.02	5.38	80	20	4	6	8
Thomsons Lake	1.91	10.70	35	0	6	8	6
Victoria Reservoir	0.21	18.20	40	20	6	0	4
Yangebup Lake	0.75	2.50	65	30	6	4	4
Average ± se	0.8 ± 0.20	8.2 ± 1.94	54.5 ± 2.72	19.7 ± 3.16	4.6 ± 0.27	5.5 ± 0.42	5.1 ± 0.31

There was only one site with evidence of *H. chrysogaster* where southern brown bandicoots (*Isoodon obesulus*) were also detected. However at sites where there was no evidence of water-rats, southern brown bandicoots were recorded at 12 of 32 sites, with up to 13 captures within a week (Fig. 4). This trend was not significant for the occurrence (chi-square, p=0.238) or abundance (t-test, p = 0.164) of bandicoots caught at sites with and without *H. chrysogaster*. In contrast, the introduced black rat (*Rattus rattus*) was captured at all sites with *H. chrysogaster* presence (Fig. 4), with a significant positive relationship (chi-square, p = 0.001). *R. rattus* was also captured at 11 of 32 sites without *H. chrysogaster*. A positive trend also existed for the

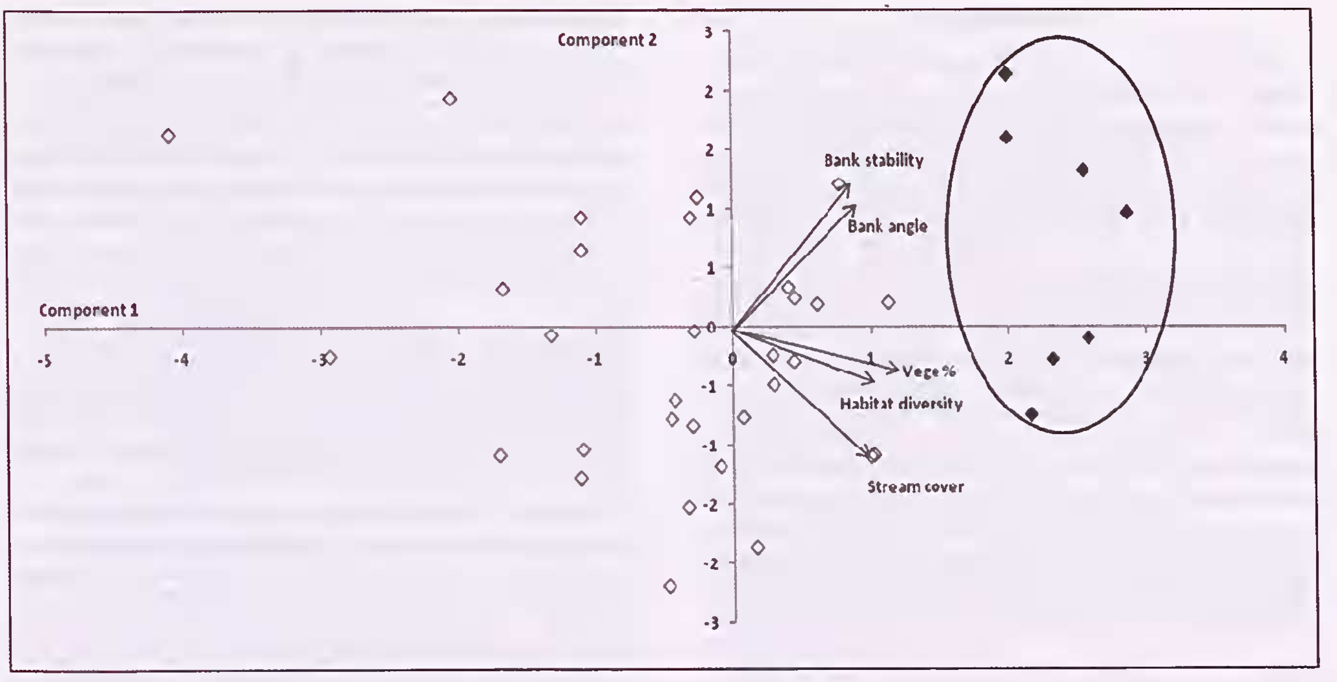

Figure 3. Principal Component Analysis of sites: Components I and 2. Positive sites (n = 7) are grouped with black markers and circled. A bi-plot from the origin identifies the trend of each habitat variable in relation to each component. Positive sites are significantly different in both Component 1 (p = 3.32 x 10^{-7}) and Component 2 (p = 0.038) values compared to negative sites (n = 32). Significance is set as α = 0.05

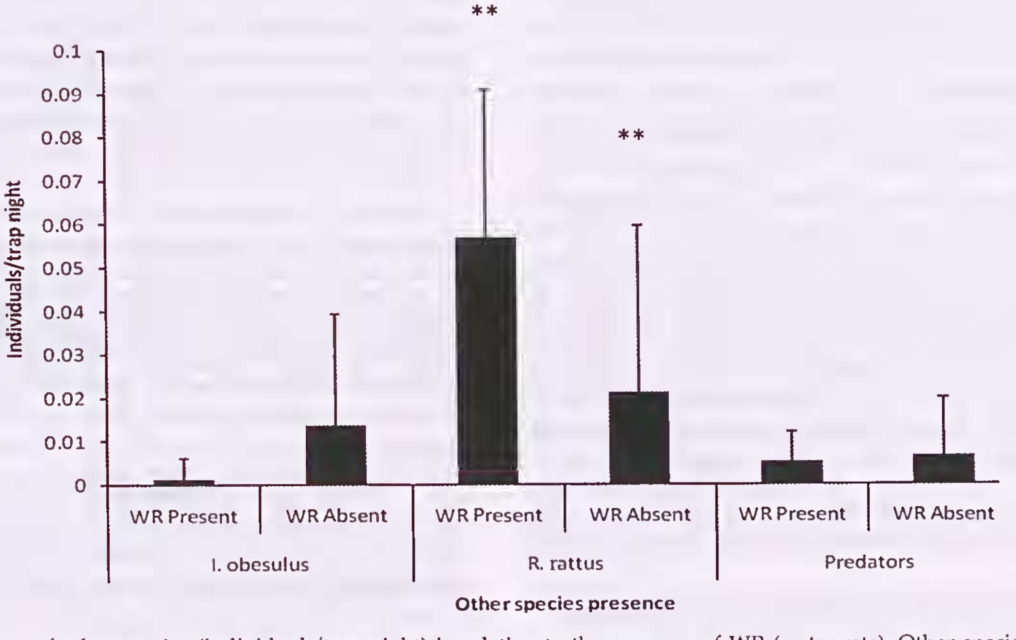

Figure 4. Presence of other species (individuals/trap night) in relation to the presence of WR (water-rats). Other species included are southern brown bandicoots (*I. obesulus*), black rats (*R. rattus*) and predators (cats, snakes, dogs, foxes, raptors). Species abundances are ± standard error. ** denotes statistical significance α = 0.05

number of *R. rattus* (individuals/trap night) caught at sites with and without *H. chrysogaster* (t-test; p < 0.001).

Predator species recorded during the study included domestic cats (*Felis catus*), tiger snakes (*Notechis scutatus*), Australian ravens (*Corvus coronoides*), European red foxes (*Vulpes vulpes*), domestic dogs (*Canis lupus familiaris*) and raptorial birds such as wedge-tailed eagles (*Aquila audax*).

Three of the seven sites with water-rats and 12 of 32 negative sites, had strong evidence of predator occurrence. No significant relationship existed between the occurrence of predator species (chi-square, p = 0.792) or abundance of predators (t-test, p=0.714) observed per trap night between sites with and without *H. chrysogaster* (Fig. 4).

Discussion

The striking feature of this study was the low numbers of water-rats captured, especially at sites where populations are known to persist. This study captured two individuals at Lake Goollelal and none at Loch McNess, where 11 and 5 captures were made respectively in autumn 2008 using similar methods (Valentine *et al.* 2009). Trapping can be an unreliable method of measuring abundance in some species. It has been suggested that *H. chrysogaster* is easily captured only where individuals are numerous (Valentine *et al.* 2009) and that capture success rate is seasonal (Harris 1978). Harris (1978) found that there were fewer captures than expected for males during winter, spring and summer, and for females fewer captures were made during winter and spring. This may be due to reductions in population sizes during the year following autumn due to social stress and reduced activity patterns in response to depleted food resources. Drops in water temperature may contribute to these lower feeding activity patterns, as water-rats are unable to regulate their body temperature effectively (Fanning & Dawson 1980). By contrast, autumn is the peak season for young to disperse and as a result more individuals are observed (Harris 1978). Therefore, small population sizes due to seasonality may have contributed to the low capture success rate here.

The results indicate that the presence of *H. chrysogaster* in Perth is linked to a number of different habitat quality characteristics. A positive correlation was found between the size of the wetland and the presence of water-rats, where the average study site size for positive sites was 2.04 km^2. Home range sizes of the species have been recorded between 0.9 km^2 (Harris 1978) to 3.9 km^2 (Gardner & Serena 1995), where individuals can use between 0.4 km^2 (Harris 1978) to 3.1 km (Gardner & Serena 1995) of habitat in a single night. These studies were, however, conducted on Eastern states populations of *H. chrysogaster*, and may not be representative of populations in south-western Australia. The smallest site with evidence of *H. chrysogaster* in this study was 0.56 km^2 (Bickley Brook), although this site is connected to the Canning River to provide a broader water source (up to 21 km^2). It can be concluded that in order to sustain a viable population of *H. chrysogaster*, the size of the water source must be large to incorporate the localized movement patterns and intra- and inter-sexual territoriality recorded for the species (Gardner & Serena 1995).

Although all sites with evidence of *H. chrysogaster* were permanent water sources, no statistical trend was observed between water depth and species presence. Most literature describing observations of *H. chrysogaster* in Australia have outlined the importance of permanent water for the species (see Scott & Grant 1997; Valentine *et al.* 2009) although they have been recorded in temporary water sources (Atkinson *et al.* 2008). Harris (1978) reported that *H. chrysogaster* rarely hunted in waters deeper than two metres, preferring to forage in proximity to the shore. Therefore the lack of positive trend could be seen as beneficial for the long-term success of the species in regards to predicted climatic changes of declining rainfall and groundwater levels (GSS 2009).

H. chrysogaster was found at sites with habitat characteristics of "high value", where sites scored highly for a high percentage of vegetation cover, stream cover and habitat diversity. More importantly, all sites with a high degree of habitat quality were positive for *H. chrysogaster* occurrence. Loss of remnant vegetation on the Swan Coastal Plain may therefore be a contributing factor to the decline in *H. chrysogaster* populations. The high percentage of vegetation and stream cover at positive sites may highlight the importance of minimizing exposure to both terrestrial and raptorial predators, as snakes and raptorial birds are known predators of young water-rats (McNally 1960). Previous studies confirm these results, where trapping success of *H. chrysogaster* was greater at water systems with offshore islands or reeds beds (Valentine *et al.* 2009), and where sites had a high percentage of riparian vegetation, shade and overhanging trees (Scott & Grant 1997).

The diet of *H. chrysogaster* is catholic, ranging from vertebrates such as fish, birds, reptiles, and mammals to invertebrates such as molluscs, crustaceans and insects (Woollard *et al.* 1978; Scott & Grant 1997; Atkinson *et al.* 2008). A diversity of habitat types within a single water system would be ideal to maximize exposure to different food items. This diversity becomes important between seasons when the species may have to switch between terrestrial and aquatic dietary items in response to changing water levels. The majority of sites with *H. chrysogaster* had greater bank angles and bank stability. This habitat selection is likely to be a response to the nesting behaviour of the species, as water-rats often burrow into river banks, creating nests at the end of tunnels (Atkinson *et al.* 2008). This therefore requires the integration of bank stability combined with a steep bank angle to prevent flooding, and possible offspring mortality, during periods of high water levels.

Although previous studies on semi-aquatic mammals have shown that predation is a detrimental and critical factor determining distribution in otherwise suitable habitats (*e.g.* Barreto *et al.* 2001), this study was limited because predation of *H. chrysogaster* could only be inferred by unexpected captures of predators such as cats, or indirect evidence. Even a small degree of predation on water-rat offspring could have a critical impact on the success of a population due to the low reproductive output compared with other rodent species such as *R. rattus*, as litter sizes range between 1–7 offspring, with 3 the average (Scott & Grant 1997). Our study was however limited by a relatively small data set, and hence we could not establish a direct link between the distribution of *H. chrysogaster* and predators.

The black rat is an introduced species held partially responsible for the extinction of many small mammal species on islands off the Western Australian coast, for example *Bettongia lesueur, Petrogale concinna, Rattus fuscipes* and *Pseudomys sp* (Morris 2002). While it is a fierce competitor with other native rodent species, a greater abundance of *R. rattus* was found at sites where *H. chrysogaster* were present. However, *R. rattus* is presumed to hold a different ecological niche to that of *H. chrysogaster*, being an opportunistic omnivore in comparison to the predominantly carnivorous and aquatic water-rat (Weir 2004). It is suggested that the two species could probably co-exist without detrimentally impacting each other (Weir 2004). However, the results of this study show that, per trap night, *R. rattus* is more abundant where there is evidence of *H. chrysogaster*. *R. rattus* may scavenge off the feeding middens left by *H. chrysogaster*, or exhibit a preference for sites of high habitat quality also favoured by *H. chrysogaster*. However, the distribution of this commensal species is confined almost exclusively to the vicinity of human settlements and *R. rattus* is not considered a significant pest of agriculture (Taylor 1975). An extension of this study into the more rural regions of the Swan Coastal Plain may reduce the significance of this interaction.

Hydromys chrysogaster was suggested as a species critical to the persistence of functional wetland systems due to its role as a semi-aquatic predator, and as a potential bioindicator in relation to wetland habitat quality in south-western Australia (Valentine *et al.* 2009). The results presented here indicate that the core habitat requirements of *H. chrysogaster* are linked to high habitat qualities, including increased stream cover, bank stability, vegetation cover and habitat diversity. Importantly, all wetland habitats of high quality had evidence of *H. chrysogaster* presence. Although seasonality may have contributed to the low capture rates, the low number of sites with *H. chrysogaster* necessitates some degree of caution, and further studies should trap for the species outside the immediate Perth area in the south west. The impact of turbidity should also be incorporated into future studies, as water-rats hunt using visual cues under water. Our study suggests that this species may be viable as a bioindicator of wetland quality on the Swan Coastal Plain, Western Australia, although it is probably not an economic, nor rapid means of assessment due to the difficulty of implementing surveys, unless a less costly method of survey, such as motion detecting cameras, was employed.

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